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Electric Machines

26/3/2015

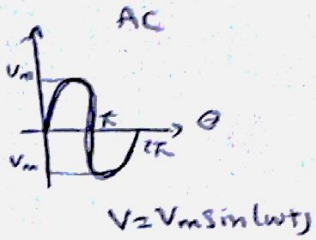
Lec 6: Single Phase AC transformer

Outline of lectures:

1. Introduction "Transformer" المحول
2. Mutual Induction الحث التبادلي
3. Transformer Construction
4. Transformer ratio
5. emf equation of a transformer

I Transformer

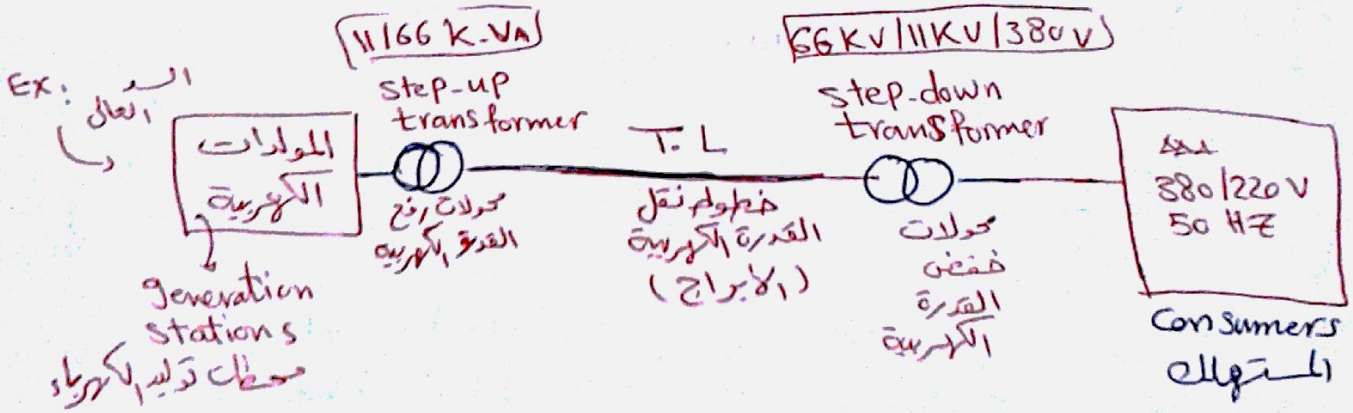
AC: Alternating current (التيار المتغير (المتردد



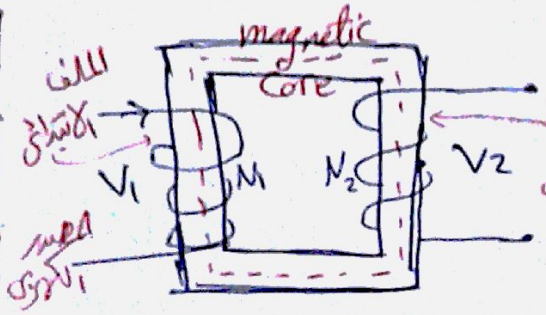
الجهد المتولد AC ⇐

$V = V_m \sin(\omega t)$

- آحادي الوجه (طور) → Single Phase (220 V, 50 HZ)
- ثلاثي الوجه (طور) → Three phase (380/220 V, 50 HZ)



Transformer ⇐ [static Machine] (ثابت) ⇒ Mechanical losses = 0



$$e.m.f = N \frac{d\phi}{dt}$$

N: عدد اللفات

* يتكون المحول من ملفين من النحاس (ملف ابتدائي، ملف ثانوي) وقلب من الحديد

* يتغير الجهد V_1 فتتغير ϕ وتتولد V_2 (قوة دافعة كهربية emf)

② Mutual Inductance

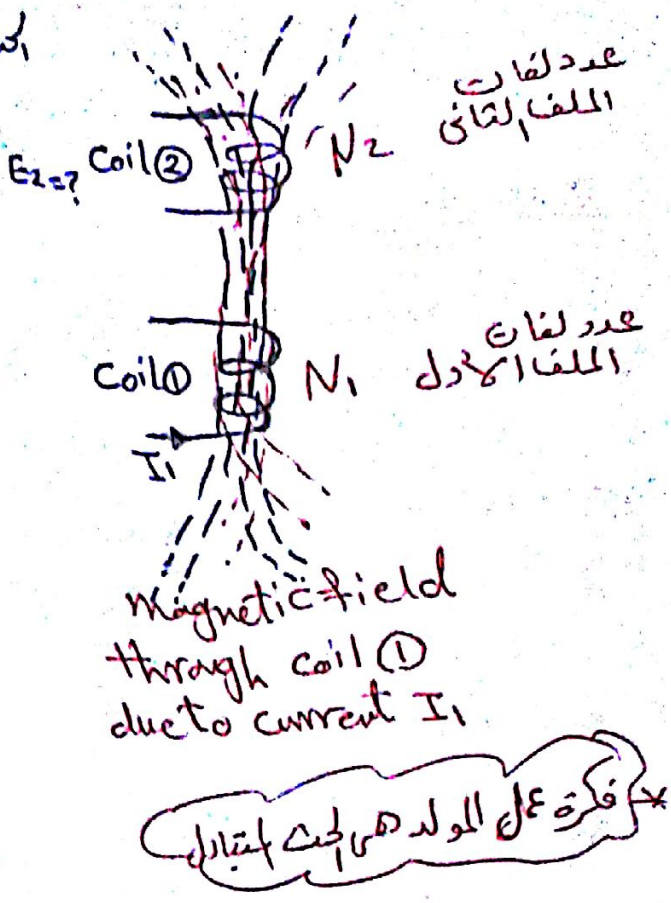
* By varying I_1 as induced emf associated with the changing in magnetic flux in coil ②

$$E_{21} = -N_2 \frac{d\phi_{21}}{dt}$$

$$N_2 \frac{d\phi_{21}}{dt} \propto \frac{dI_1}{dt}$$

$$\therefore N_2 \frac{d\phi_{21}}{dt} = M_{21} \frac{dI_1}{dt}$$

M_{21} = Mutual inductance between coil ① & coil ②



Also, in a similar manner

$$E_{12} = -N_1 \frac{d\phi_{12}}{dt}, \quad N_1 \frac{d\phi_{12}}{dt} = M_{12} \frac{dI_2}{dt}$$

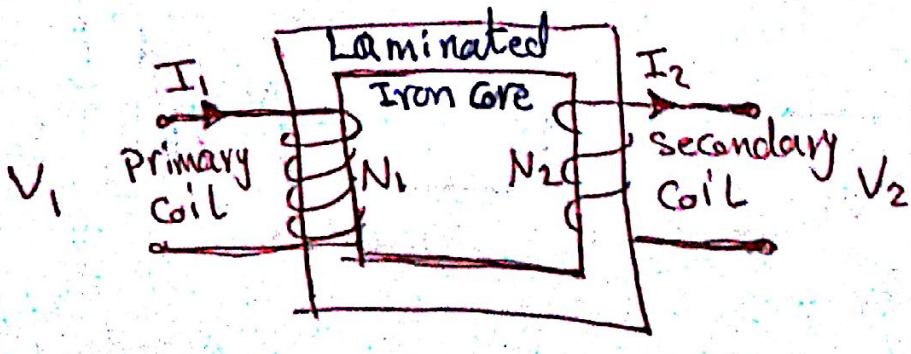
$$M_{12} = M_{21} = M = \text{Mutual induction}$$

Transformer Construction

Two coils

- Primary
- Secondary

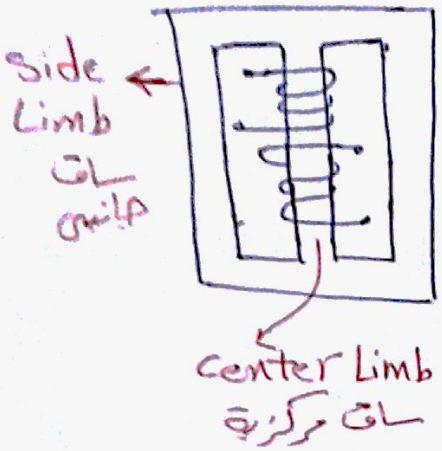
Magnetic Core

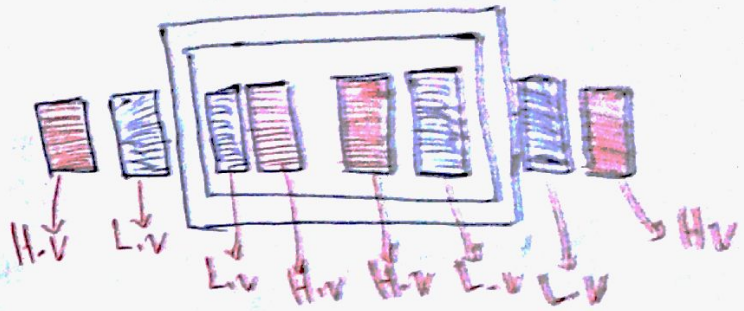


- " A transformer is an electric device, using the phenomenon of mutual inductance to transfer electric energy from one circuit to another circuit "

Types of transformer

- Shell type
- Core type





L.V ⇒ low voltage
H.V ⇒ high voltage

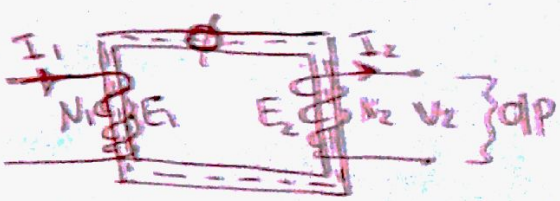
: State the types of AC transformer and Compare between them? اذكر انواع المحولات وقارن بينها

- Transformation ratio نسبة التحويل

$$\boxed{E_1/E_2 = N_1/N_2}$$

E_1 = induced emf on primary coil
N_1 = No of turns of Primary Coil
E_2 = induced emf on secondary coil
N_2 = No of turns of secondary coil

No copper losses ($=0$)



$V_1 = E_1$, $V_2 = E_2$

$$\boxed{E_1/E_2 = V_1/V_2 = N_1/N_2}$$

V_1 → Source voltage
V_2 → load voltage

$$V_1/V_2 = N_1/N_2$$

$$\boxed{V_2 = \frac{N_2}{N_1} V_1}$$

if $N_2 > N_1 \Rightarrow V_2 > V_1$ ⇒ (step-up transformer)

if $N_2 < N_1 \Rightarrow V_2 < V_1$ ⇒ (step-down transformer)

emf equation of a transformer

Prove that : $\boxed{E = 4.44 f N \phi_m}$

where: (E) is the induced voltage
(f) is the frequency
(N) is the Number of turns
(ϕ_m) is the max. flux density

Let $\boxed{\phi = \phi_m \sin \omega t}$

$$E_1 = -\frac{N d\phi}{dt} = -N \frac{d(\phi_m \sin \omega t)}{dt}$$

$$E_1 = -N \phi_m \frac{d \sin \omega t}{dt} = \boxed{-N \phi_m \omega \cos \omega t}$$

$$\therefore \boxed{E_1 = N \phi_m \omega \sin\left(\omega t - \frac{\pi}{2}\right)}$$

$$\boxed{\cos(30) = -\sin(-60) = -\sin(30 - 90)}$$

$\omega = 2\pi f$

$$\therefore E_1 = 2\pi f N \phi_m \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$E_1 = E_{1\,max} \cdot \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$E_{1max} = 2\pi f N \phi_m$$

$$\therefore E_{1\,rms} = \frac{E_{max}}{\sqrt{2}} = 4.44 f N \phi_m$$

$\Rightarrow \boxed{V = V_m \sin \omega t}$

$\therefore$ rms value of

$$E_1 = 4.44 f N_1 \phi_m$$
$$\& \quad E_2 = 4.44 f N_2 \phi_m \Big\} \; E_1/E_2 = N_1/N_2$$